The SMAP Level-4 ECO Project: Linking the terrestrial water and carbon cycles

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(2) Universities Space Research Association, GESTAR
(3) Science Systems and Applications

Outline

1. The Level-4 ECO Project
2. Catchment vs. Catchment-CN
3. SMAP Level-2 Passive Assimilation
4. Modeled vs. Observed FPAR
5. Next Steps

The L4-ECO project

Objective: Develop a fully coupled hydrology-vegetation data assimilation algorithm to generate improved estimates of hydrological fields and carbon fluxes

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Land surface hydrology impacts biosphere (carbon fluxes), but not vice versa

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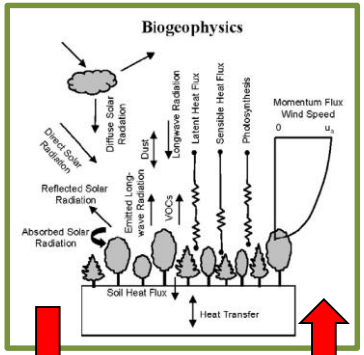
L4 ECO:

- Catchment-CN: Coupled land surface hydrology model (Catchment) and dynamic vegetation model (CLM4) to allow full feedback

Catchment-CN (*Koster et al., 2014*)



CLM4 dynamic vegetation model (*Oleson et al., 2010; Thornton et al., 2007*)

Catchment land surface model (*Koster et al., 2000; Ducharne et al., 2000*)

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  - SMAP brightness temperatures (Tbs)

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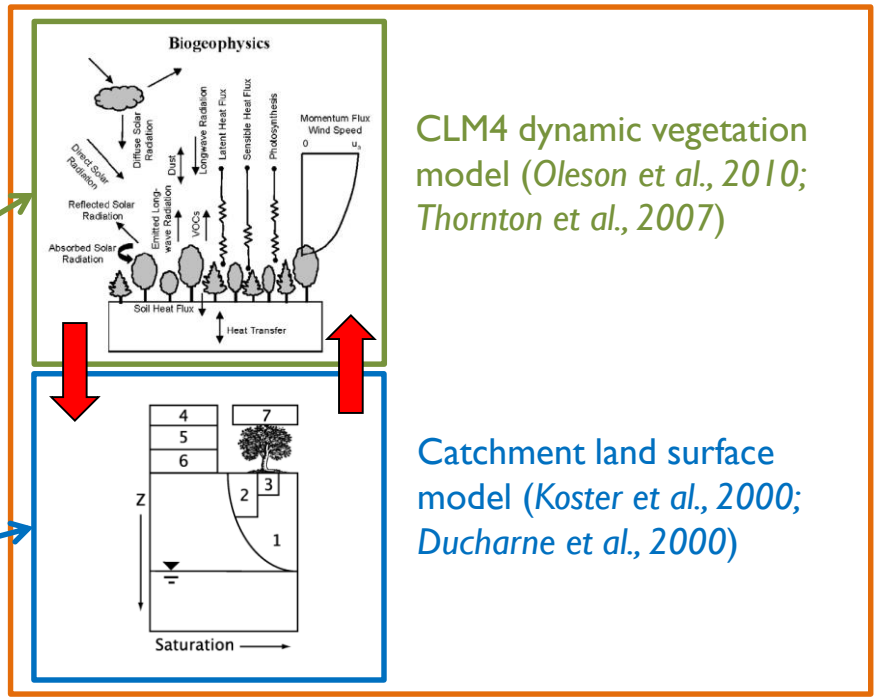

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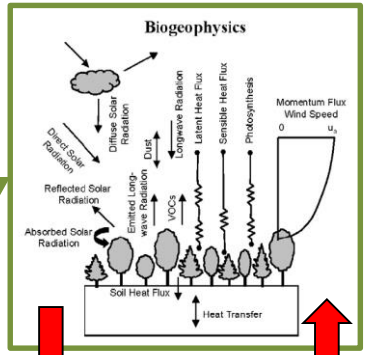

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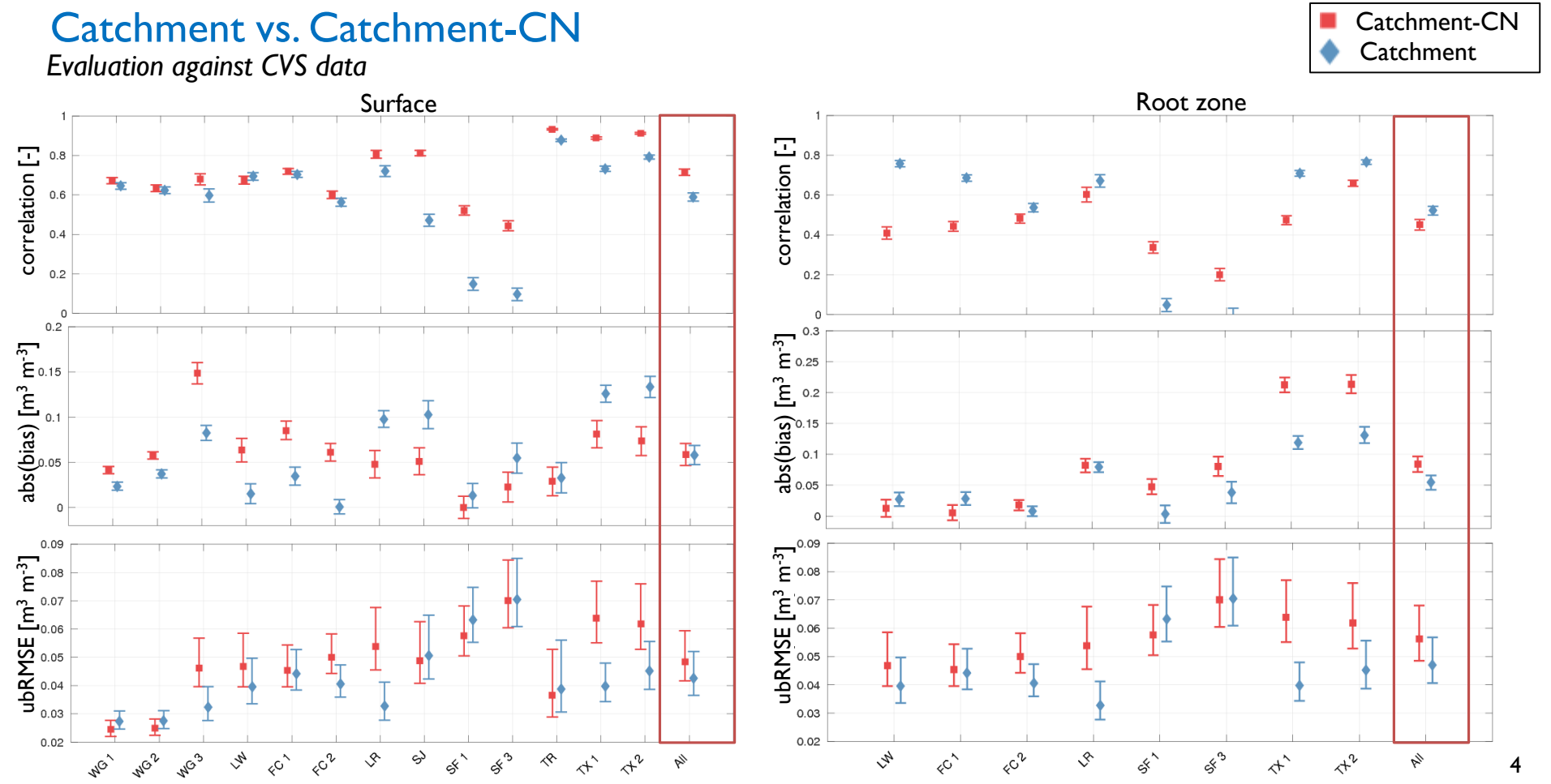
Generate improved estimates of hydrological fields and carbon fluxes

Catchment vs. Catchment-CN

Evaluation against CVS data



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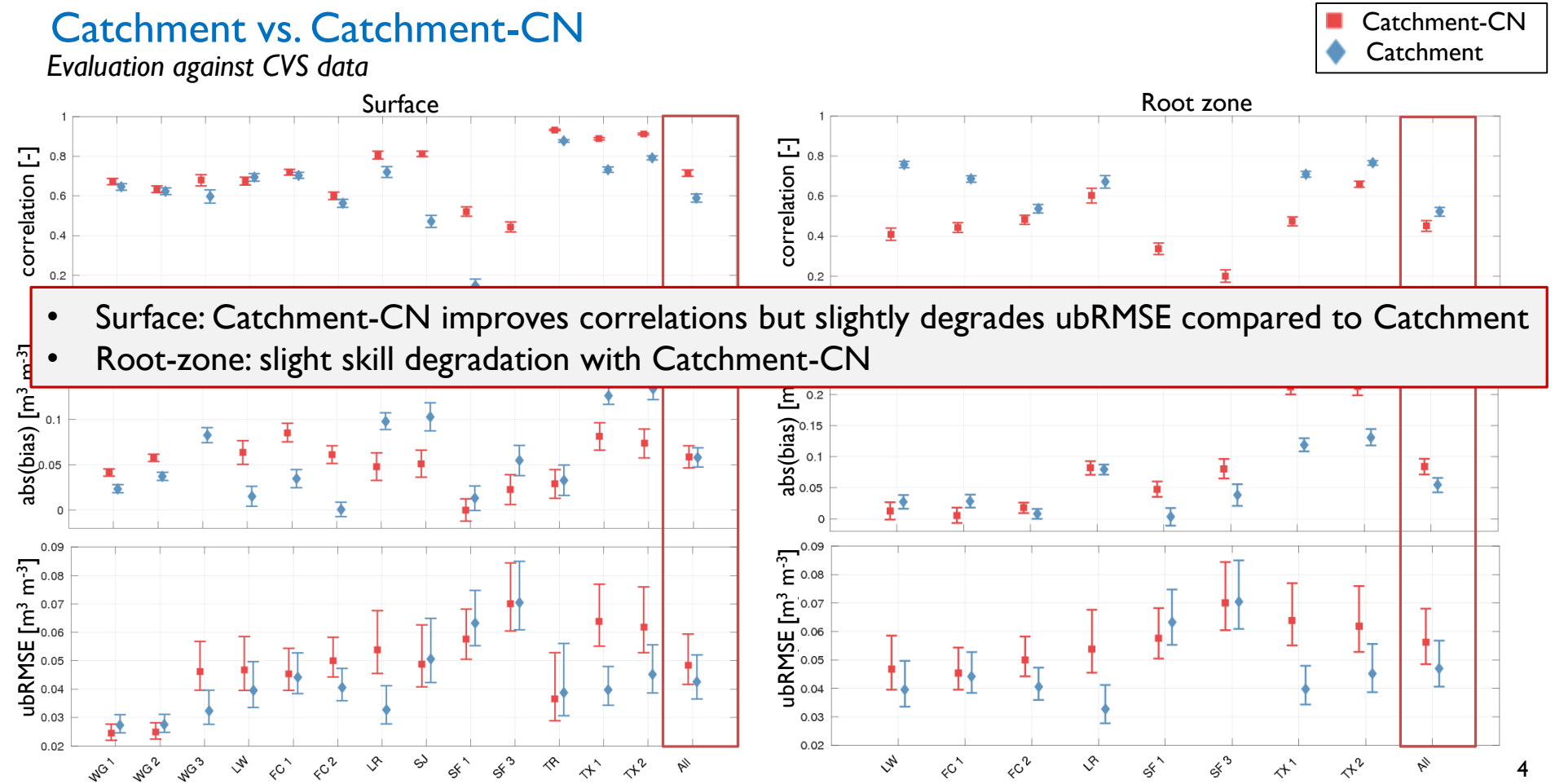

- Surface: Catchment-CN improves correlations but slightly degrades ubRMSE compared to Catchment
- Root-zone: slight skill degradation with Catchment-CN

Assimilation of SMAP L2SMP

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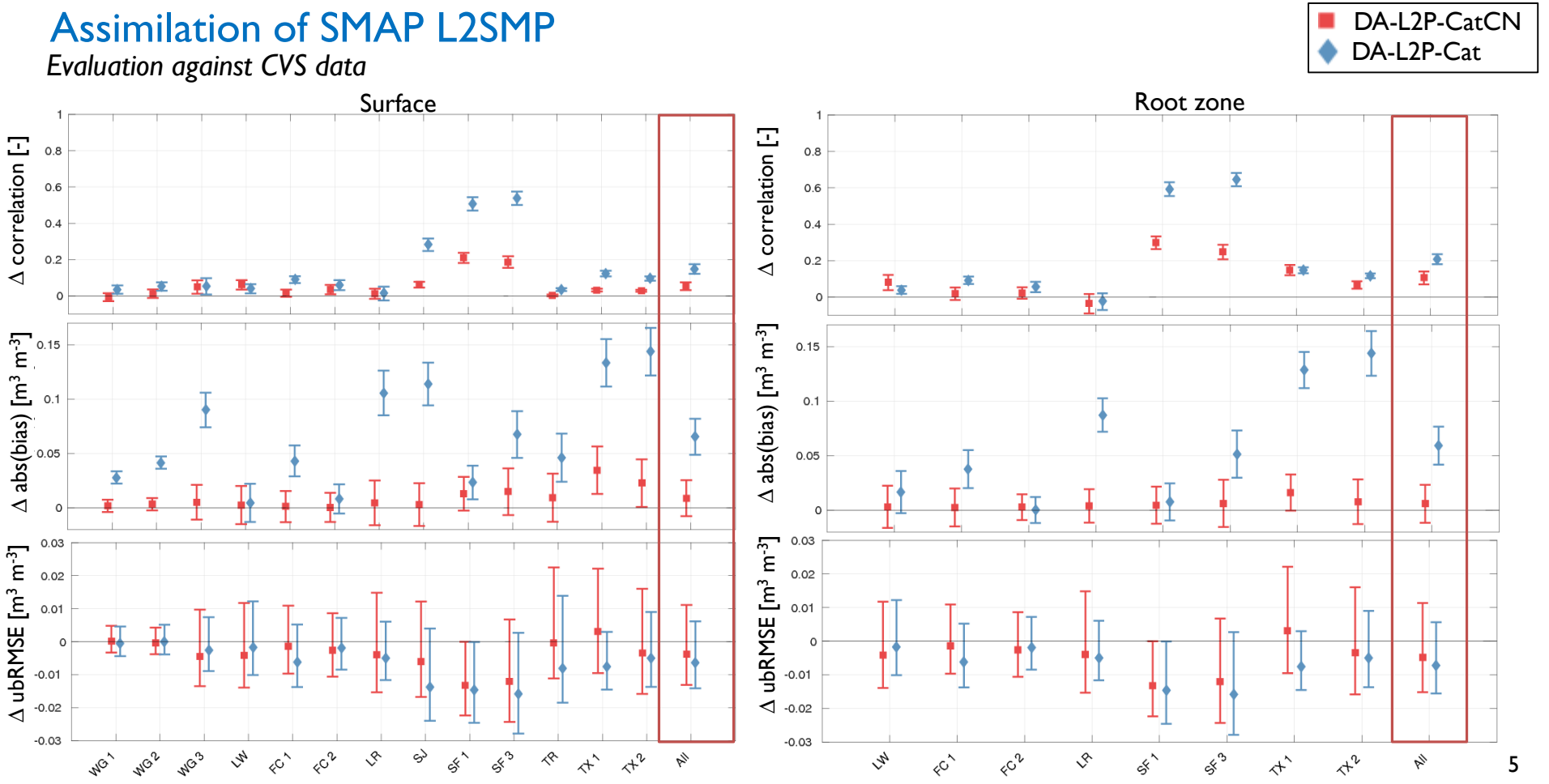

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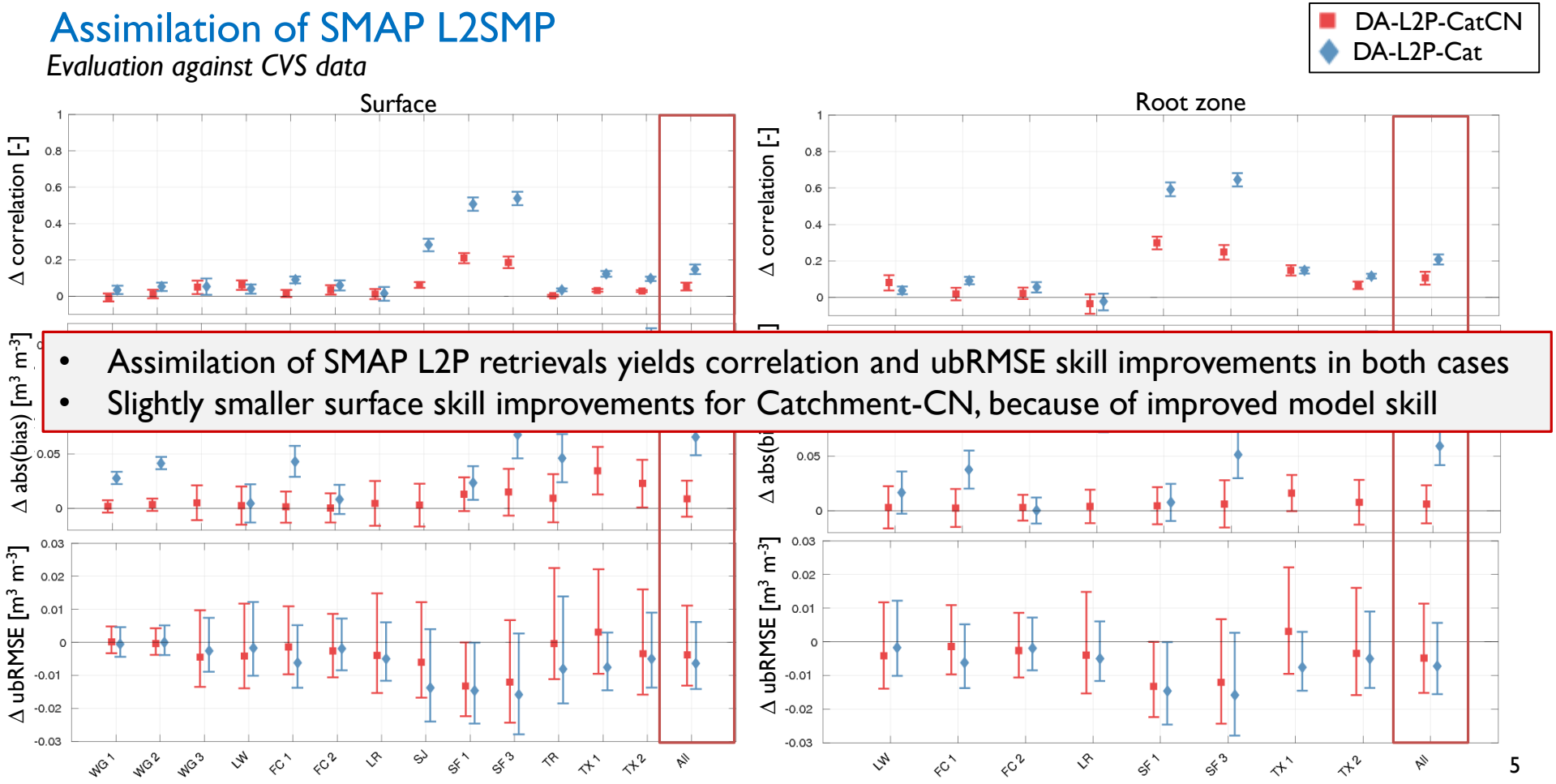
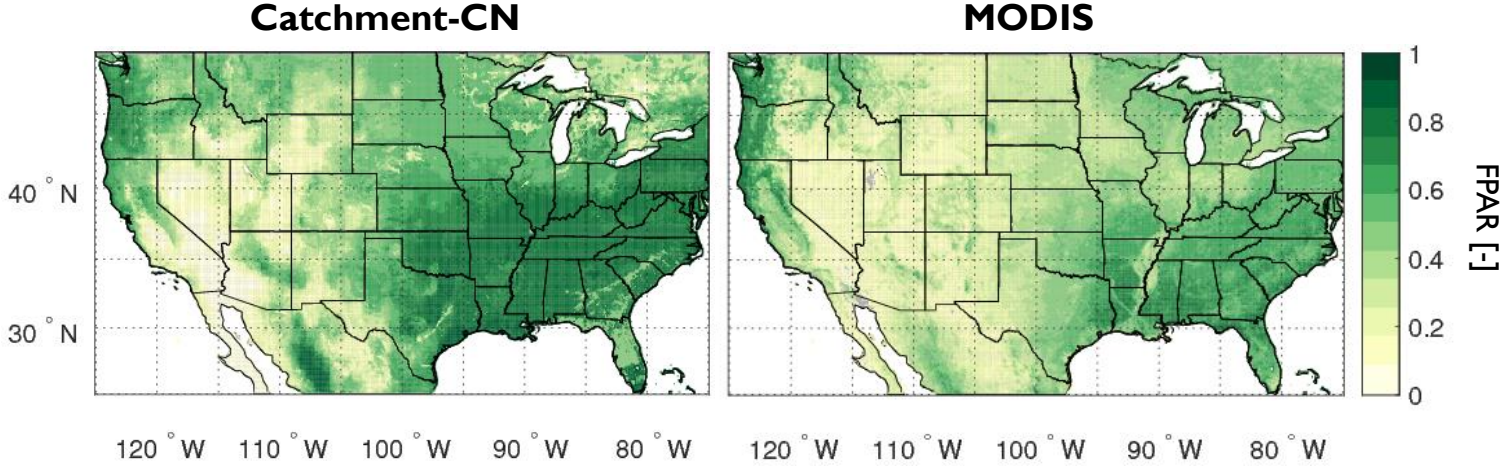


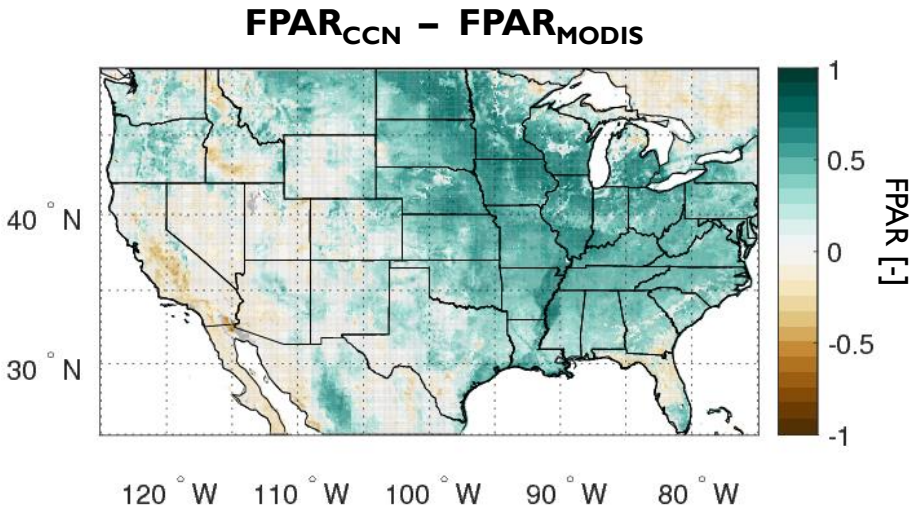
- Assimilation of SMAP L2P retrievals yields correlation and ubRMSE skill improvements in both cases
- Slightly smaller surface skill improvements for Catchment-CN, because of improved model skill

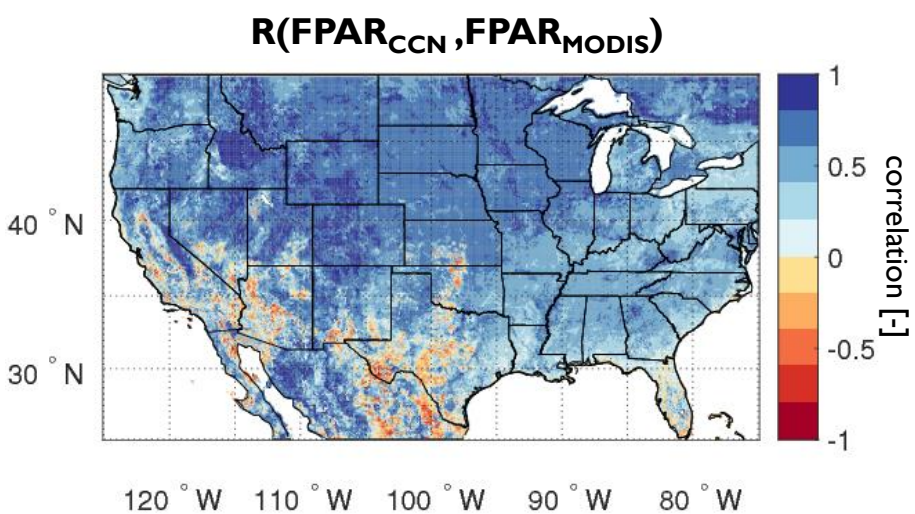
Catchment-CN FPAR vs. MODIS FPAR



Mean FPAR Apr 2015 - Mar 2017

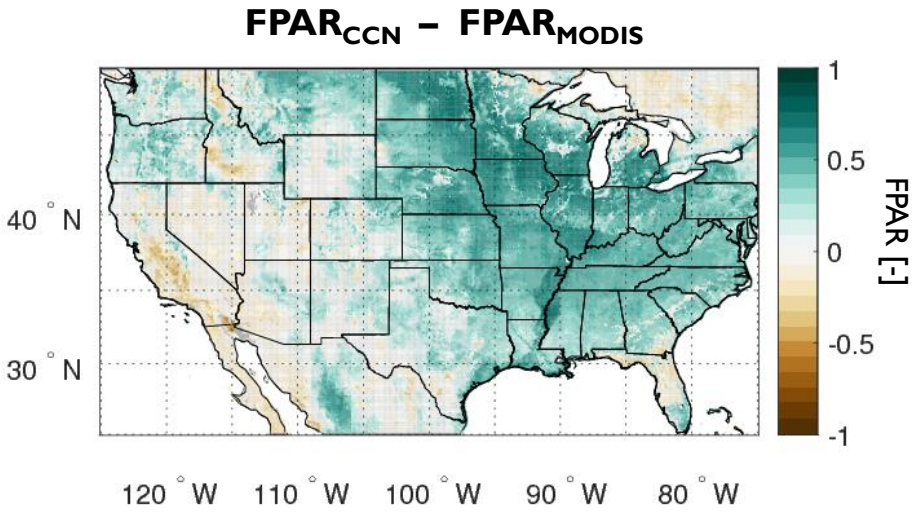
Catchment-CN FPAR vs. MODIS FPAR

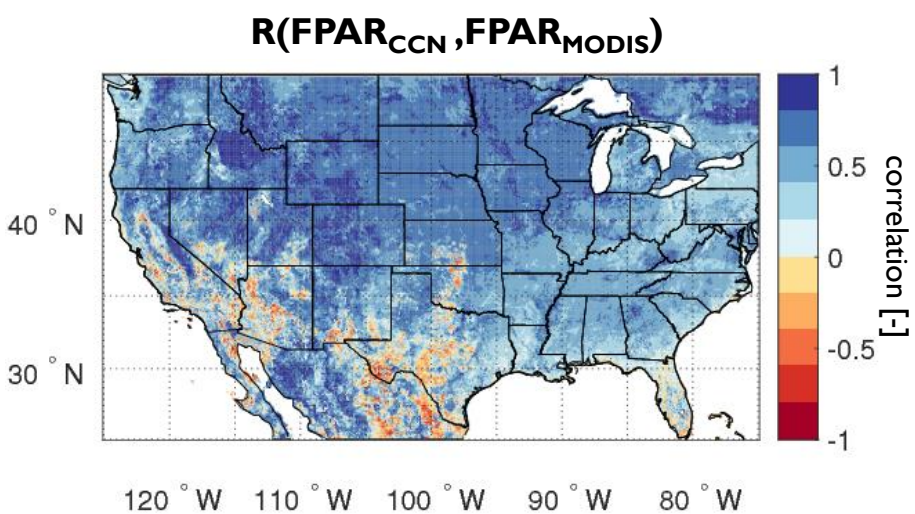




- Model and observations show strong discrepancies in absolute values and dynamics
- Differences may be too large to correct through assimilation alone

Catchment-CN FPAR vs. MODIS FPAR





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→ calibrate Catchment-CN to obtain more realistic model simulations

Next steps…

(1) Calibrate Catchment -CN

- Use MODIS FPAR observations to estimate optimal vegetation parameters for Catchment-CN
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(3) Data generation

- Use fully coupled data assimilation system to generate improved estimates of hydrological fields and carbon fluxes

Thank you!

References

Reichle, R.H., Koster, R., Collatz, G.J. (NASA ROSES 2015 - SUSMAP), The SMAP Level 4 Eco-Hydrology Product: Linking the terrestrial water and carbon cycles through the joint assimilation of SMAP data and MODIS and OCO-2 vegetation observations

Koster, R. D., M. J. Suarez, A. Ducharne, M. Stieglitz, and P. Kumar (2000), A catchment-based approach to modeling land surface processes in a general circulation model 1. Model structure, *J. Geophys. Res.*, 105(D20), 24,809–24,822, doi:10.1029/2000JD900327.

Ducharne, A., R. D. Koster, M. J. Suarez, M. Stieglitz, and P. Kumar (2000), A catchment-based approach to modeling land surface processes in a general circulation model 2. Parameter estimation and model demonstration, *J. Geophys. Res.*, 105(D20), 24,823–24,838, doi:10.1029/2000JD900328

Koster, R. D., G. K. Walker, G. J. Collatz, and P. E. Thornton (2014), Hydroclimatic controls on the means and variability of vegetation phenology and carbon uptake, *J. Climate*, 27, 5632 - 5652.

Keith W. Oleson, David M. Lawrence, Gordon B. Bonan, Mark G. Flanner, Erik Kluzek, Peter J. Lawrence, Samuel Levis, Sean C. Swenson, Peter E. Thornton (2010) Technical Description of version 4.0 of the Community Land Model (CLM)

Thornton, P. E., J.-F. Lamarque, N. A. Rosenbloom, and N. Mahowald (2007), Influence of carbon-nitrogen cycle coupling on land model response to CO2 fertilization and climate variability, *Global Biogeochem. Cycles*, 21, GB4018, doi:10.1029/2006GB002868.

EXTRA SLIDES

Assimilating SMAP L2P SM into Catchment-CN

Evaluation against CVS data